Phase 1 Project Summary

Firm: Orbital Technologies Corporation

Contract Number: NNX13CC36P

Project Title: Acoustic Resonance Reaction Control Thruster (ARCTIC)

Purpose of the Research:

The overall objective of the Phase 1 effort was to demonstrate the technical feasibility of the Acoustic Resonance Reaction Control Thruster (ARCTIC) concept. Unlike state-of-the-art reaction control thrusters that use toxic hypergols, delicate catalyst beds, or high-voltage spark systems to affect rapid ignition, ARCTIC uses the gas dynamic phenomenon known as acoustic resonance to autogenously heat the propellants beyond the autoignition temperature. There are many potential applications for combustion devices based on acoustic resonance ignition in the space propulsion industry. The niche that ARCTIC has been designed to fill is to scavenge residual low-pressure propellants from a spent upper stage such as a Centaur or Delta stage. By using this residual propellant, ARCTIC can provide supplemental impulse following sustainer engine cut-off (SECO) in a launch vehicle upper stage with minimal additional propulsion system infrastructure. The ARCTIC thruster is being designed to reduce the complexity of ancillary in-space propulsion systems required to perform missions such as propellant settling, orbit circularization, attitude control, and deorbit burns for orbital debris mitigation.

Description of the Research Carried Out:

Design requirements were defined for the ARCTIC-1 thruster prototype that was built and tested in Phase I. This thruster was sized to deliver 89 N (20 lb_f) of vacuum thrust at a chamber pressure of 69.0 kPa (10 psia) with oxygen and hydrogen delivered at supply pressures and temperatures consistent with the conditions expected to be found in a spent upper stage. The Phase I experimental work focused on characterizing the resonance cavity performance at sea-level and vacuum conditions, and gaining an understanding of the resonance heating characteristics required for rapid, reliable thruster ignition. In an effort to optimize the combustion efficiency of the thruster, three types of secondary propellant injectors were also evaluated. In addition to the experimental activities, a conceptual flight-weight ARCTIC thruster was designed for Phase II implementation. During Phase II program, ORBITEC will develop a flight-weight prototype of the acoustic resonance thruster, the ARCTIC-2, in coordination with a major space propulsion system integrator.

Phase 1 Result:

Test campaigns conducted at sea-level and at simulated altitudes of 100,000 ft and higher demonstrated that the ARCTIC thruster can provide rapid and repeatable ignition with low pressure hydrogen and oxygen gases. During these hot-fire tests, there was no erosion of the resonance cavity components or degradation of the thruster hardware. Conditioning the propellants to near-cryogenic temperatures reduced the temperature of the resonance gas, though it did not inhibit ignition. In fact, the ARCTIC-1 test article was able to generate an ignitable mixture of hydrogen and oxygen even when the bulk driver gas temperature was reduced to 215 K. It is believed that through further optimization, this threshold could be reduced even further. The ARCTIC-2 thruster concept was advanced to maturity level consistent with a ConDR.

Justification for Phase 2 Continuation:

The Phase I project demonstrated the technical feasibility of the Acoustic Resonance Reaction Control Thruster concept by meeting all of the technical objectives and answering the technical questions. The ARCTIC-1 prototype demonstrated that low-pressure propellants can be used effectively to achieve rapid ignition, and that high combustion efficiency device can be obtained in an acoustic resonance combustion without risk of damaging the hardware or suffering from performance degradation. The ARCTIC technology is an efficient, lightweight method for NASA to produce primary or auxiliary impulse to support future exploration of the Solar System.